Tampereen yliopisto

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DEVELOPMENT OF SHIPOWNERS' INSPECTION AND ACCEPTANCE METHODS DURING THE SHIPBUILDING PROCESS

Master's Thesis

Unit of Automation and Mechanical Engineering
Examiners:
Professor, Asko Ellman
University teacher, Ilari Laine
October 2019

ABSTRACT

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This master's thesis was made for SHg Consutling Oy about the development of inspection and acceptance methods during shipbuilding. SHg Consuting Oy is a one-person consulting company for project business in the maritime industry. The company's knowledge is born through long term and comprehensive yard experience, specially in cruise ship building. The general manager has written her doctoral thesis about the shipbuilding process and production efficiency. The consulting company's clients are shipyards, shipowners, design offices and maritime turnkey contractors.

The problem of this thesis can be summarized in one research question: What are the best practices to verify shipowner's requirements concerning the systems specified in the ship contract? The objective was to research what acceptance and inspection methods are being used now in the shipbuilding industry and what theoretical methods are available. There was a theoretical research about the methods available and three main methods are listed in this master's thesis. Then the methods were compared with product-driven development table.

After the theoretical part, there were some interviews made for the Finnish navy purchasing organization. I visited Royal Caribbean Cruise Lines to learn about their acceptance methods at the Meyer shipyard in Turku, Finland. There was a newbuild that was delivered a few weeks after my visit to the shipyard. This visit provided ample information about how things are done in practice. Also, it was good to see how acceptance methods vary between a commercial shipowner which has several similar boats and the navy that has special purpose vessels of many different kinds and with special demands.

The result of the comparison between methods was to research more the V-model which was then chosen to be used in a sample case to make it more understandable. The V-model can be described as a way of thinking. Further research could be related on how timeline or deadlines could be integrated into the V-model and how the system could be combined with a document database software.

The originality of this thesis has been checked using the Turnitin OriginalityCheck service.

TIIVISTELMÄ

Ville Raiko: Varustamon rakennusaikaisten valvonta- ja vastaanottomenetelmien kehitys
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Tämä diplomityö tehtiin toimeksiantona SHg Consulting Oy.lle, joka on ruskolainen yhden hengen konsultointi toimisto. Kyseisen yrityksen asiakkaina ovat telakat, laivavarustamot, sekä muut meriteollisuuden parissa työskentelevät yritykset ja organisaatiot.

Diplomityön tutkimusongelma voidaan tiivistää yhteen lauseeseen: Mitkä ovat parhaat keinot laivasopimuksen mukaisten vaatimusten täyttämiseen. Työssä pyrittiin selvittämään mitä keinoja on yleensäkin olemassa teoreettisella tasolla ja lisäksi selvitettiin millaisia järjestelmiä tällä hetkellä on käytössä. Teoriaosuudessa valittiin kolme metodia, jotka vastaivat parhaiten tutkimuskysymykseen ja niitä analysoitiin tarkemmin. Apuna käytettiin taulukkoa, josta parhaat pisteet sai V-malli.

Teoriaosuuden jälkeen tutustuttiin käytännön tasolla tällä hetkellä käytössä olevaan malliin. Tutustumiskohteena oli Royal Caribbean Cruise Lines:in rakenteilla oleva alus Meyer Turun telakalla. Laiva luovutettiin muutama viikko tutustumisen jälkeen, joten vastaanotettavia laitteistoja oli useita erilaisia. Käytännön vierailu osoitti millaisia menetelmiä maailman toiseksi suurin varustamo käyttää. Lisäksi haastateltiin merivoimien logistiikkalaitoksen työntekijöitä, jotka vastasivat kysymyksiin vastaanottomenetelmistä. Heillä oli kokemusta vuonna 2016 valmistuneesta alusluokasta, sekä tällä hetkellä suunnitteluvaiheessa olevasta laivue-2020 hankkeesta.

Lopputuloksena tutkittiin V-mallia ja siitä tehtiin järjestelmä, jota voi soveltaa erilaisiin teknisiin järjestelmiin. Kyse on ajatusmallista jota voi soveltaa prosessien hallinnassa. Helpomman hahmottamisen ja konkretian luomiseksi käytettiin esimerkkiä, joka löytyy jokaisesta aluksesta, sen kokoa ja käyttötarkoitusta katsomatta.

Jatko tutkimuksena voidaan tutkia miten V-malliin saisi integroitua aikajanan. Lisäksi voitaisiin tutkia miten V-mallin saisi integroitua jo käytössä olevaan dokumenttienhallinta järjestelmään. Tarkastuksessa on käytetty Turnitin OriginalityCheck palvelua.

PREFACE

This thesis is made for SHg Consulting oy in Finland. SHg consulting is a consulting company working mainly for Royal Caribbean Cruises Ltd. The purpose of this thesis is to create a model for verification system that can be used in several organizations that own vessels and are purchasing vessels. This master's thesis includes the background section where the problem is described, a theoretical part where different types of solutions are researched, the empirical section which includes a detailed description of the V-model, and the conclusions. The idea for this thesis was mine and I found Dr, Sisko Hellgren who has extensive experience in this area. After a few meetings we decided this could be an area of research to write a master's thesis about. My original idea has developed through the several years I have done work in shipyards. I found out that several ship owners in Finland rely mostly on the shipyard's methods. This is not usually a problem in Finland because the Finnish shipbuilding quality is one of the highest in the world. Another thing that I have noticed is that there could be a place for an entire business network in this area. SHg consulting Oy is a one-person consulting company and the CEO of the company has several years of experience in shipbuilding processes. The company works already in nearly the same area as this masters' thesis. This master's thesis aims to create a base for using a model for the work that is being done already in practice. Writing this thesis has been challenging but highly rewarding to see that possible customers are already interested in the new service provided. This thesis has greatly supplemented my studies at Tampere university.

I would like to thank Sisko Hellgren for all the help that she has offered during this major project. She has helped and answered my questions and solved problems and supported me when writing was not so easy. She also made it possible to visit and get to know how the verification work is done for one of the world's biggest shipowners.

Finally, I would like to thank my family and friends for the support and understanding during this project. Especially my mother who made a huge effort and helped with the translations and grammar, and for my father for the great ideas and practical viewpoint of the industry.

Rusko, 10.10.2019
Ville Raiko

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LIST OF SYMBOLS AND ABBREVIATIONS

AQAP	Allied Quality Assurance Publications
DNV-GL	Den Norske Veritas
FAT	Factory Acceptance Test
GQAR	Government Quality Assurance Representative
HAT	Harbor Acceptance Test
HVAC	Heating, ventilation, and air conditioning. Generally used in cruise ships' cabin engineering
IACS	International Association of Classification Societies
IMO	International Maritime Organization
ISO	International Organization for Standardization
PDD	Product Driven Development
PDCA	Plan Do Check Act method
RCCL	Royal Caribbean Cruise Ltd.
RINA	Registro Italiano Navale
SAT	Sea Acceptance Test
TK	Turn Key (contractor)

1. INTRODUCTION

1.1 Background

Shipyards in Finland come in several different sizes, each one with its own way of supervising its work and the quality of its products. On average, Finnish shipyards have a good quality control and the product quality is of a high standard. The good product quality is partly due to the Finnish workers' way of thinking that things are done properly or not at all. Also, the good quality control and know-how of the supervisors has a critical role in making ships. Even though there is a good quality control, basically every time some issues occur after the ship has been delivered. Fixing these problems is very expensive for the shipyard and affects the shipowner's income when the ship is docked unscheduled. Most of the times these problems should have been noticed already during the production or at least in the quality control. However, since the quality relies on human action, there will always be some issues.

In this thesis, the focus is mainly on the ship owner's inspection and acceptance methods. There will also be some examples of the shipyard's inspection methods because they are quite similar after all. When the shipowner can ensure the ship is correctly constructed, it can minimize the unscheduled maintenance and thus contributes to the financial benefit of all involved. When the inspection methods are well designed, it is possible for the ship owner to purchase its ships from less expensive shipyards because it can trust its own quality control. Of course, the shipowner cannot specify every technical detail of the new build. The shipyard must give some options to the customer.

The main objective is to reduce additional work that may occur when a problem arises after receiving a work that has been checked and accepted and everything needs to be done again. This causes additional costs for the shipowner and the shipyard; also its very frustrating to see things done twice in a factory. Another thing is that schedules are very tight and even the smallest delays on subassemblies may affect in the main assemblies' implementation.

One subject of this research is the V-model. The V-model name comes from the shape of the graphical structure. It also stands for Validation model or Verification model. The V-model is used often in software coding and by big organizations, such as NASA and national governments.

Other compared validation and verification methods are called waterfall-model and agile-model. All of these methods are widely used in the software development. Software development industry has many good solutions that are suitable also for shipbuilding industry.

This thesis was made for a small consulting company and the subject is very abstract so there is no concrete end product; the aim of this thesis is to create a method and for and end product a case-based study is needed to get some kind of a real life baseline or point of comparison. After the case example the theoretical part can be understood more easily. Research strategy is a case-based structure. The theoretical background comes from the literature and know-how of the company. There is also an interview which is used for general background.

1.2 Research case company and context

The following thesis work has been done for SHg Consulting Oy located in Rusko. The company works as a consulting company for project business in the maritime industry. The company's knowledge is born through long term and comprehensive yard experience, especially in cruise ship building. The CEO has written her doctoral thesis about the shipbuilding process and production efficiency. The clients are shipyards, shipowners, design offices, and maritime turnkey contractors. Royal Caribbean Cruise Ltd is a shipowner for which SHg Consulting has recently been the project manager responsible for accepting two newbuild ships. The six companies of Royal Caribbean Cruises Ltd. employ 65,000 people from over 120 countries. In this area of business, it is important to have good contacts from the shipyard and from the ship owner. It also requires wide technical know-how of the systems generally used in ship building. RCCL is the world's second biggest cruise shipowner and it has several newbuilds under construction or development all around the world. [1] The shipowners rely mainly on the technical quality of the shipyard. This method works well for the shipowner when things work correctly and plans and development are well made.

The problems occur when there are requirements that are left to the judgment of the shipyard and the shipyard does not have sufficient know-how to make the system reliable. If the ship owner does not have a good checking or acceptance method, the system is accepted even if it does not fulfill the requirements. This causes additional work after everything is completed and the bill falls on the shipowner because the system was accepted.

To prevent this situation, the shipyards nowadays detail their specifications, so it is easy to test. This is not a big problem in cruise ships that basically are made in production line and the ships have very similar technologies and systems. The challenges begin when something new must be created, for example, in a special purpose vessel that has many systems integrated. When systems are integrated together the importance of detailed subsystem specification is emphasized.

The verification process begins already in the development phase, when requirements are listed and designed. During this process the verification methods are designed and created.

This thesis is all about quality control after all. Quality control includes so many things that every step of the manufacturing process must involve a specific quality control. The main goal of quality control is to make sure that the customer, person, government, or organization, gets the product or service that it has paid for. This thesis researches about the quality control from the shipowner's that is the customer's point of view. Usually the customer is able to trust on the quality control system of the manufacturer, but because a ship, especially a special purpose vessel, is a very complicated system it is hard to detail all the requirements, and human errors occur easier. The goal is to create a customer-friendly quality control system that is easy to apply and gives a more coherent approach to the system acceptance, including subassemblies.

1.3 Shipbuilding process

Shipbuilding is a very complicated and time-consuming process. The entire process includes several different kinds of tasks and subprocesses that link to each other technically and in schedules. [15] Today, a shipbuilding project is a collaboration of a huge network of design offices, authorities, classification societies, material suppliers, and turnkey (TK) contractors together with the shipyard. This scenario means that the shipyard needs to have the ability to control its network in order to be successful. A portion of the suppliers and TK contractors participate in the tendering phase, i.e., when the shipyard is offering the ship to the owner. The long co-operation has resulted in many highly specialized companies which are absolute tops in their field. [13]

Shipbuilding relies a lot on different standards and rules. This is due the international nature of the business. The most widely accepted organization that determines several general standards is ISO, International Organization for Standardization. They make several standards and the most used in marine business is ISO9001. It is a quality management standard. [18] It can be used to ensure quality of a product or a service. In the context of this master's thesis the part 8. "Operation" is interesting. The ISO9001 requires that the processes of the organization are described and documented correctly. Often used method to fulfill the part 8 of the ISO9001 is the Plan-do-check-act or PDCA method.

In theory, the ISO9001 suits very well the shipbuilding process, but it is very general so every organization must fine-tune the standard to fit their own processes.

1.4 Research questions and research methods

The problem in the newbuilds' acceptance methods for shipowners is that they rely on the shipyards' acceptance methods and systems. The methods used by shipyards are good when the newbuild is of a kind known for the yard, meaning it is a cruise ship or a tanker or a ro-ro vessel, overall a vessel type that has been built before several times and does not include several different kinds of deck machineries that are integrated together. At the other end is a special purpose vessel that can be one of a kind in the whole world, like a naval ship or an oil recovery ship or a vessel built for some special underwater infrastructure build or maintenance job. The system testing and verification must be designed during the development of the system because the system and its subassemblies are very complex.

This thesis is based on one main research question: what are the best practices to verify ship owner's requirements concerning systems specified in the ship contract? This one question sums up the purpose of this research. This question came up after the first meeting at the RCCL office. The goal is that all parties involved in the shipbuilding process agree about the specifications and take the necessary steps to fulfill these specifications. It is important that the shipowner and yard understand what they want the vessel to be capable of. These are questions that are not so critical in cruise shipbuilding but stand out in special purpose vessels. This would be the case for example if the newbuild is a pipeline-laying vessel designed to lay a certain amount of pipeline on the sea floor, and after the ship has been fully working for one month it is discovered that the pipeline laying speed is only 80% from the designed speed. This naturally creates unexpected costs and delays.

The shipyard answers to the needs of the customer, in this case a shipowner, but if the shipowner has not specified the requirements, the shipyard may not have the technical know-how to solve the problem and this leads to a system that needs to be repaired or upgraded afterwards. In general terms, the shipyard makes what the customer needs, but when the customer is unsure the shipyard goes by the cheapest way and this causes later problems, delays, and costs to the shipowner.

This master's thesis subject is relatively abstract and to understand how the methods can be improved it needs be understood how the acceptance methods are done in practice. By using several research methods it can be ensured that this thesis includes the necessary theory and that the theory can be applied in practice. That is one main reason it was decided to use three main research methods. The methods were:

- Literature study
- Interview study
- Active research

In the beginning was a literature study which included a search matrix to gather information about shipbuilding process overall and what kind of acceptance methods are existent. This was the most time-consuming research method. The literature was mainly searched from Google scholar, which is Googles search engine for academic research, Springer, which is as international publisher specialized in scientific literature, and Andor which is Tampere university's library that includes several different databases.

The second research method used was an interview study. Interviewing is a fundamental and obvious form of research. We want to know things about some persons point of view, so we ask them. And they tell us. People can be helpful that way, and most want to be helpful to some degree and this leads to a accurate research method. [24] It was done at the same time as the active research. The interview study gave detailed information about the acceptance methods in non-civilian organizations. The interview was done in Finnish and then translated into English. The interview was done with a method that gathers new information and the questions were logical and designed so that they are easy to answer.

The third research method was active research. This provided the most information about the systems being used now and how acceptance and verification are done in commercial shipyards. The active research was done in Turku Meyer shipyard. The newbuild was for RCCL and the tests that were made were harbor acceptance tests. All these methods complement each other. Information from these three different research methods is used to create a wholeness that can be understandable.

Observation can also be used as a research method. Observation can produce information during several years and is a key factor in know-how. [23] In this thesis information gathered by observation is used in the work practices part. Observation can be useful when you are trying to understand an ongoing process or behavior, or an unfolding situation or event, and also when there is physical evidence, or products or outcomes that can be seen.

1.5 Focus area and exclusions

When building a new ship there are several systems and assemblies that need to be tested and verified. In this thesis the aim is to create a checklist-style verification method. Since a ship is such a big and complex system, it is unrealistic to make a verification method that suits every part of the ship, but rather the aim is that the method is suitable for verifying technical systems. Thus, there are some main exclusions:

- Steel structure
- Hull assemblies
- Electrical systems
- Architecture and interior design
- Naval electronic systems such as
    - Radars
    - Autopilot systems

The verification methods researched are ideal for assemblies that have several different types of subassemblies, such as

- Bilge water systems
- HVAC systems
- Propulsion system
    - Engine
    - Thrusters
    - Couplings
- Deck machinery
    - Mooring systems
    - Cranes
    - Ramps / bow doors

The common factor for these systems is that they have many different kinds of subsystems that require special knowledge in their area. For that reason, the subsystems need to be verified before the main system can be tested and verified. Also, all the subsystems can be tested as a subsystem, they do not need to be installed to do the testing.

The focus is to create a general guideline that can be modified for each system individually. The modification is always work that requires special know-how about the system that is being developed. The case company's work is now mainly this kind of verification of the systems and subsystems. They are using the verification method used by the shipyard. This is a method that works very well, but it depends mainly on the shipyards' IT systems.

1.6 Description of the problem

Many organizations that offer a service or a product have very good systems to verify their own products and often customers can rely on these systems because they pay for that. When the product itself is starting to become very complex and has several new technologies and innovations, the customer should not rely only on the suppliers' systems. This is because the customer might have a more detailed know-how of the systems they really need than the supplier. Also, it is critical to ensure that every system works as designed in all conditions, and only the customer can predict all the possible scenarios.

Usually a master's thesis has a relatively concrete problem that then lead to a concrete answer to that problem. The content of this thesis is abstract. This causes that the problem is also abstract and the definition is very ambiguous. The problem can be summed up in one sentence:

What are the best practices to verify shipowner's requirements concerning systems specified in the ship contract.

This is the same phrase as the research question. The problem is not a concrete problem because companies can survive without modifying their process management systems, but because technology goes forward and the main key for more efficient working is to improve their work and way of working constantly. And when an organization can work more efficiently, it is always a positive sign and something everyone should aim to.

2. THEORETICAL BACKGROUND

2.1 Newbuilds parties

When a shipowner decides to order a new ship, there are basically three parties: the shipowner is in the customer's role, the shipyard is the manufacturer, and the classification society is the competent authority. The classification society is a non-governmental organization in the shipbuilding industry. [5] The customer has some requirements, for example:

- passenger capacity
- architectural design
- interior design details

These requirements are aspects that make the cruise ship more attractive for future customers, so they are not very much related to safety or technical details.

The customer does not specify in detail the technical requirements because they are specified in the IMO rules for classification. In the class rules are also included the safety requirements. The rules come from the standards created by IACS. There are several classifications societies such as Den Norske Veritas, Bureau Veritas and RINA. The shipyard and the classification society work in deep collaboration for obvious reasons.

Each flag state has also some special requirements for the technical and safety details. In Finland the flag states' competent maritime authority is Traficom. The classification society verifies that the technical details comply with the class rules.

In some rare cases, a classification society is not required. When building naval ships, the navy has its own classification society within its organization. This acts as the competent authority even though it is a governmental organization. The ships are built following the class standard, but each navy might have stricter rules, for example, for steel structures and fire protection. Naval ships are rarely registered to a class but there are some voluntary services. [22]

When the manufacturing process ends, the verification process begins. First, the work supervisor checks the job quality; then he shows it to the shipyards supervisor who checks the work; finally, he presents it to the classification societies and customer's representative. If there are subassemblies, this process is repeated for each subassembly and then for the entire assembly.

In the ship contract are the IMO rules that are to be enforced. The classification society confirms the rules that are applied, and the flag state is negotiated in the ship contract.

Verification and validation are measures that are applied in almost every manufacturing process. In any working and efficient factory, verification methods are deeply integrated in production management.

2.2 Verification

Verification is a process that needs to be designed simultaneously with the product itself. If the verification process is not designed properly, it will lead to the acceptance of a product even if it does not fulfill the requirements. There are quality assurance guidelines, process control procedures, quality management inspection procedures, testing procedures, and quality management auditing procedures to regulate the process to ensure that the total quality management system operates effectively and efficiently. [9] There are several quality management systems that aim to good quality by evaluating the manufacturing process. Evaluating is a step in the verification process. The most popular quality management standard is ISO9001. [7] Verification can be described as an agreement of contracts.

2.3 Verification methods

The verification process provides management tools to coordinate individuals and activities involved in a mission. Verification activities are implemented for the hardware, software, and the integrated system tests. The verification methods should always include the following steps:

a. Analysis
b. Test
c. Inspection
d. Demonstration
e. Similarity [2]

Good and well-defined requirements are critical when developing successful verifications as mentioned above. Ways to ensure that the requirements are well written are to use skilled requirement writers and the requirements should all have the next attributes:

- Product/System oriented
- Concise
- Single statement
- Measurable
- Feasible
- Verifiable
- Contain rationales
- Traceable [2]

Generally, verification can be described as in figure 1. It is critical to verify the design, the development, and the product itself.

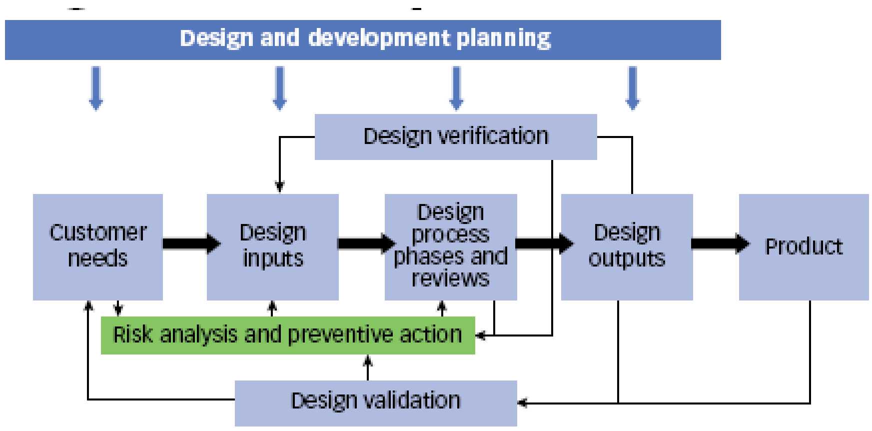

Figure 1. Sample of designing and developing process.

The Quality management system's requirements ISO9001 is a standard that almost every organization utilizes at least to a certain extent in the shipbuilding business. In part 8.2 the rules about the requirements of the products and services are found. Especially part 8.2.3 has clearly listed what needs to be included to ensure the quality of the product or service.

"8.2.3.1 The organization shall ensure that it has the ability to meet the requirements for products and services to be offered to customers. The organization shall conduct a review before committing to supply products and services to a customer, to include:

a) requirements specified by the customer, including the requirements for delivery and postdelivery activities;

b) requirements not stated by the customer, but necessary for the specified or intended use, when known;

c) requirements specified by the organization;

d) statutory and regulatory requirements applicable to the products and services;

e) contract or order requirements differing from those previously expressed.

The organization shall ensure that contract or order requirements differing from those previously defined are resolved.

The customer's requirements shall be confirmed by the organization before acceptance, when the customer does not provide a documented statement of their requirements." [18]

2.4 Process management

For a successful process management, the current process needs to be analyzed precisely and accurately. One way to analyze and represent it is to prepare a graphical process flow. The process flow includes several components such as roles, resources and events such as FAT (factory acceptance test), HAT (harbor acceptance test), and SAT (sea acceptance test) [9] There are several different types of guides and courses on how projects should be managed. The most used methods are standardized and ISO9001 is one of the most well-known standards in this area. ISO9001 is all about quality management and process management has a big role in the quality management also. A process can be described as an event that includes certain activities and these activities produce a result. Only recently have academics begun to relate knowledge to quality management and process management. The early work used analytic models to understand the relationship between quality and learning. [14] Other analytical studies about the quality and process management range from the examination of the effect of learning on quality control.

2.5 Agile model

Another researched model studied in this masters' thesis is called the Agile model. This model is old, and many companies and organizations use it as a base development model. The Agile model is a very understandable model, suitable for projects and processes that include several phases. The Agile model can be compared to the ship construction's design spiral. The Agile model is used also mainly in software development and it is very quick, as its name suggests. It is highly suitable for large projects with relatively simple development methods. If the system is more complicated, the iteration abilities of the model may become a straggler, but this does not represent a real problem until the assembly has several subassemblies that have subassemblies. Also, if the project is too complicated and needs to be tested in a very detailed way, it can be difficult to use. This model could prove to be too simple for example when building a naval vessel or a spaceship.

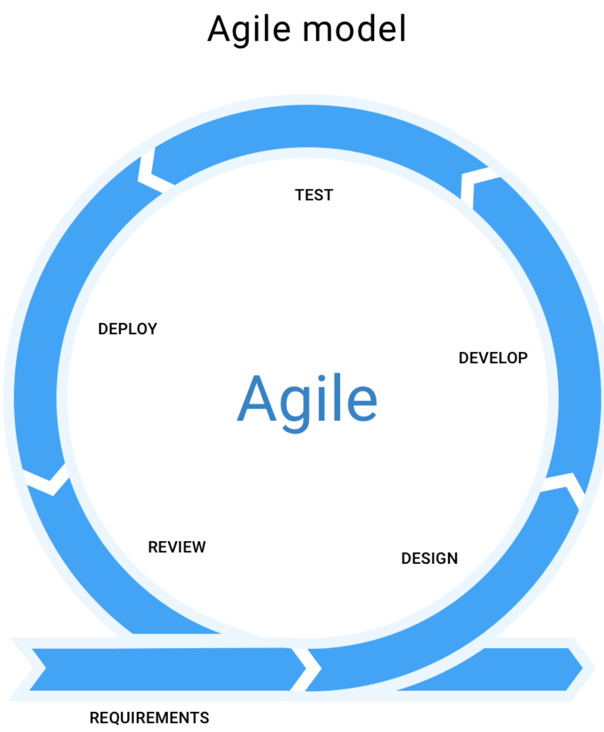

Figure 2. Sample of design and development process with Agile model.

Summarizing, the pros of the Agile model are:

- Easy to understand
- Can be scaled
- It is agile

The cons of the agile model are:

- It is not effective if there are several subassemblies that need to be tested in a very detailed manner.
- It is chronological so that the specified order needs to be followed, and if some deadline is not achieved, it may take several weeks or months to again reach the same phase where a system detail can be revised.

There is also a model called Agile–Stage-Gate which is created by Dr. Robert G. Cooper. [16] It is called a hybrid model because it includes two types of developing models. It is suitable for software development and Dr. Cooper has investigated its suitability for manufacturing processes. According to his research, Agile-Stage-Gate-model adds the most value when there is high uncertainty and a great need for experimentation and failing. [16] This means that the model can be used in a company that makes several kinds of products and the more risky products can use the Agile-Stage-Gate-model and the more traditional products can use a more simple developing method.

While the Agile-Stage-Gate-model suits very well for development, it has one big issue for the purpose of this master's thesis. It does not make it clear how the verification is taken into count during the different development phases. The Agile-stage-gate hybrid model is still relatively new so it requires more research and real life experiences.

2.6 Waterfall model

The Waterfall model is a good verification model for several different types of development. It can be scaled, and it is flexible. The Waterfall model is also widely used in software development companies. The Waterfall model is similar to the Cooper-model. In both there are stages and gates that are passed and then moved to the next stage. Each stage ends in a gate which then opens up the next stage of the development process.

The waterfall model is the Sequential development model. In the Waterfall model the requirement should be clear before going on to the next step of design or development. Testing is made once the subassembly has been fully assembled. In the Waterfall model each work-product or activity is completed before moving on to next phase and each phase of development proceeds in order, without overlapping on the next phase. The advantage of the Waterfall model is that each phase can be scheduled for the tasks to be completed within a specific period of time. This is important on the shipbuilding process when timelines are crucial and delays are not acceptable.

The documentation and testing are made at the end of each step, which helps in maintaining the quality of the entire assembly. [8]

In software development, it is simpler to clarify the requirements before the actual development of the code begins. In the shipbuilding industry, the specifications of a machinery assembly may not be as detailed or may change during the development. The pros of the Waterfall model are:

- Flexibility
- It is a linear model so it is easy to implement
- Documentation is relatively straightforward

The cons of the Waterfall model are:

- If the design is changed during the development, it is difficult to integrate in the verification model.

- It is cumbersome to make a timeline of the verification schedule

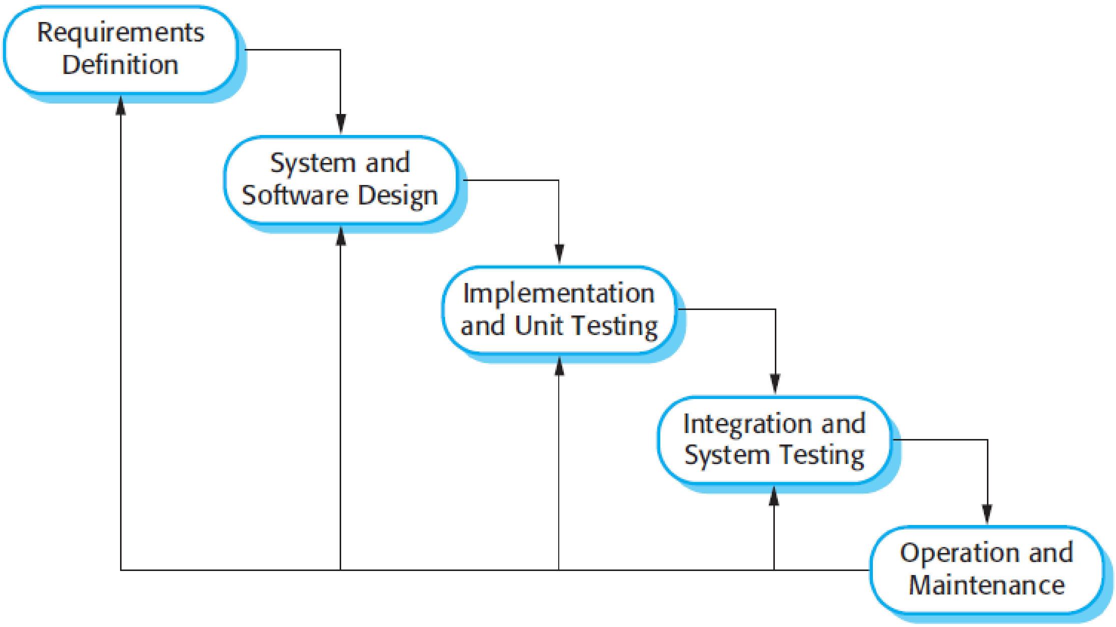

Figure 3. Sample of design and development process with Waterfall-model.

Even though the Waterfall model is easy and a straightforward design system is often very reliable and easy to understand, the Waterfall model is too simplified for a complex system. The main problem is that it is difficult to add any timeline to the process flow.

The Waterfall-model is similar to the Stage-Gate-model, also called as the Cooper-model, named after its creator Robert G. Cooper. [17]

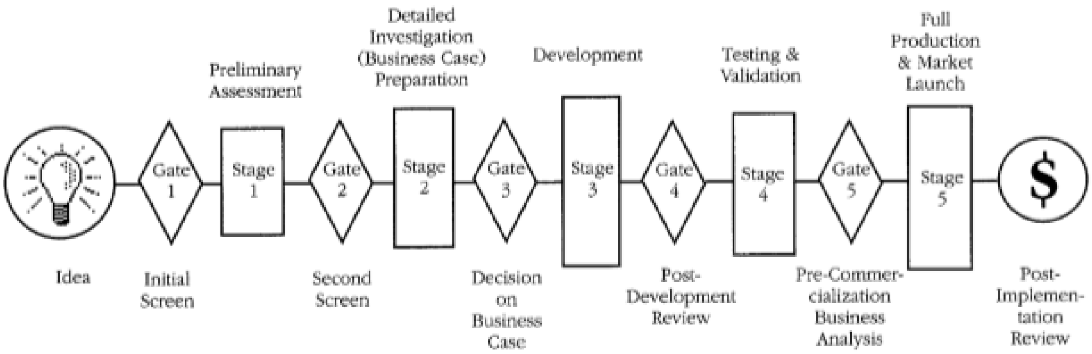

Figure 4. Ovreview of Stage-Gate model, also called as Cooper-model [17]

The stage-gate model can be used when a system or an assembly is being verified and also organizations can use this method, or a variation of this method to fulfill ISO9001 requirements. [21] The method is easy to understand and very straight forward.

2.7 V-model

The V- model comes from Validation & Verification model. The V model is a variant of the traditional Waterfall model of system or software development.

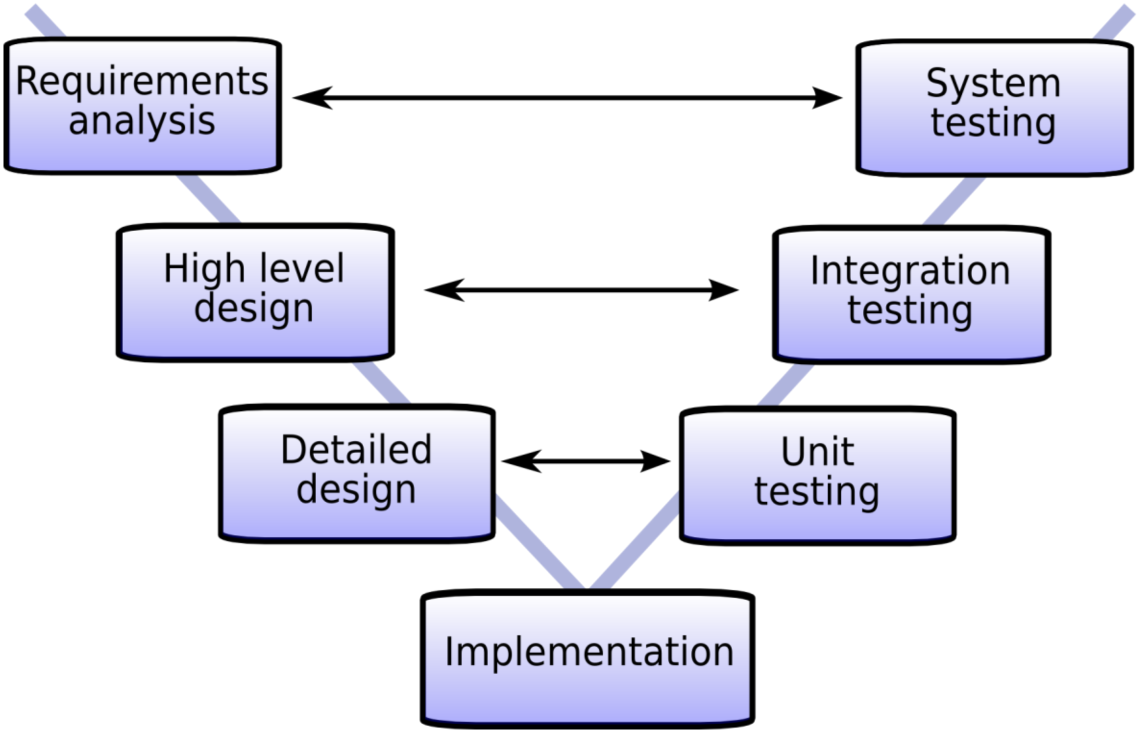

Figure 5. V-model

In the V-Model, all product development steps appear in a "V" shape from a product's design for its testing and validation. The left side of the "V" represents the design phase in which requirements and specifications of a product are identified. The right side of the "V" details the product prototype phases, their integration and different stages of product testing and validation. The base point of the "V" represents the actual implementation of product development components that include mechanics, electronics and informatics.

The V model takes the bottom half of the waterfall model and bends it upwards into the form of a “V”, so that the activities on the right verify or validate the work outputs of the activity on the left. More specifically, the left side of the V represents the analysis of the activities that decompose the users' needs into small, reasonable pieces, while the right side of the V shows the corresponding activities that aggregate and test these pieces into a system that meets the customers’ requirements.

Like the Waterfall model, the V model has both advantages and disadvantages. On the side of the advantages, it clearly represents the primary engineering activities in a logical and digestible flow that is easily understandable, while balancing the development activities with their corresponding testing activities. Developers and designers can lessen the impact of this sequential phasing limitation if they view development as consisting of many short Vs rather than a small number of big V's, one for each concurrent iterative increment.

The problem with the V model is that the distinction between unit, integration, and system testing is not as clear cut as the model allows you to think. For example, a certain number of test cases can sometimes be viewed as both subassembly and integration tests, thereby avoiding redundant development of the associated test inputs, test outputs and test data. Nevertheless, the V model is still a useful way of thinking about product and assembly development, provided that everyone involved, especially management, remembers that it is merely a simplifying abstraction and not intended to be a complete and accurate model of modern system or software development. In general terms, it is a way of thinking, not a complete system. When making people think in a certain way, the outcome is assumed to be better.

2.7.1 The V-model variants

There are three variations of the traditional V model of system/assembly development that make it more ad hoc to testers, quality engineers, and other personnel or organizations interested in the use of testing as a verification and validation method.

The single V model:

- modifies the way of the traditional V model to represent the executable work products to be tested rather than the activities used to produce them.
- is the most widely used

The double V model:

- adds a second V to show the type of tests corresponding to each of these executable work products.
- makes the method more complex but if the system has several integrated subassemblies it might be more understandable

The triple V model:

- adds a third V to illustrate the importance of verifying the tests to determine whether they contain defects that could stop or delay testing or lead to false test results, whether positive or negative
- is used more in software development, due to the nature of coding that needs to work flawlessly with other codes inside the software

Testing is a major verification technique intended to determine whether an executable work product behaves as expected or required when it is operated by known inputs. Testers test these work products by placing them into known pretest states or preconditions, operate them with appropriate inputs such as data and exceptions, and comparing the actual results postconditions and outputs with the expected or required results, to find faults and failures that can lead to underlying defects.

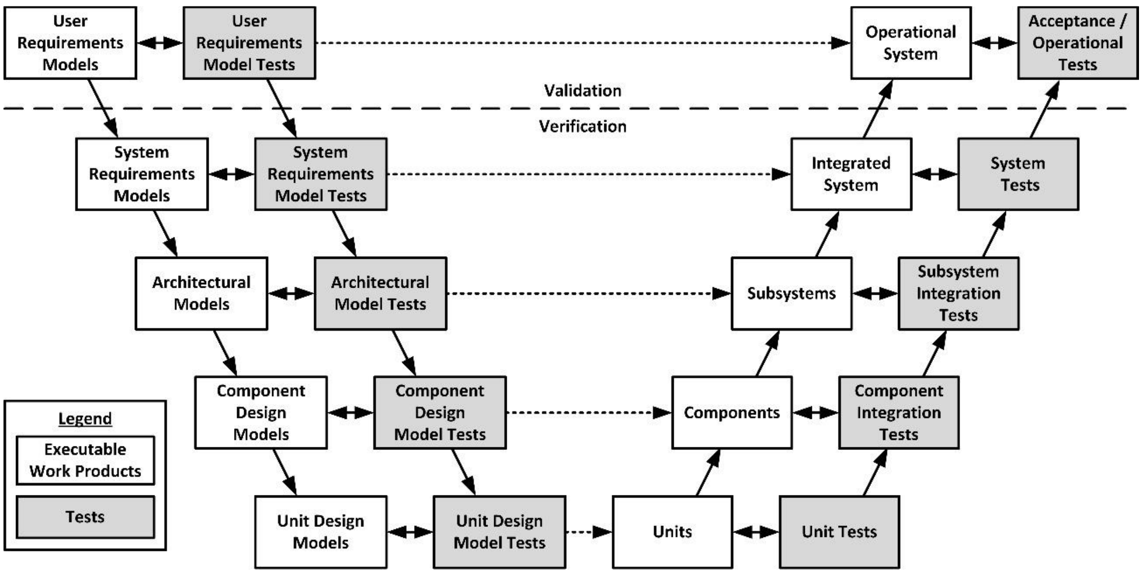

Figure 6. Double V-model.

Figure 5 shows the double-V model, which adds the corresponding tests to the single V model. The double V model allows to detect and fix defects in the work products on the left side of the V before they can flow into the system and its components or subassemblies on the right side of the V.

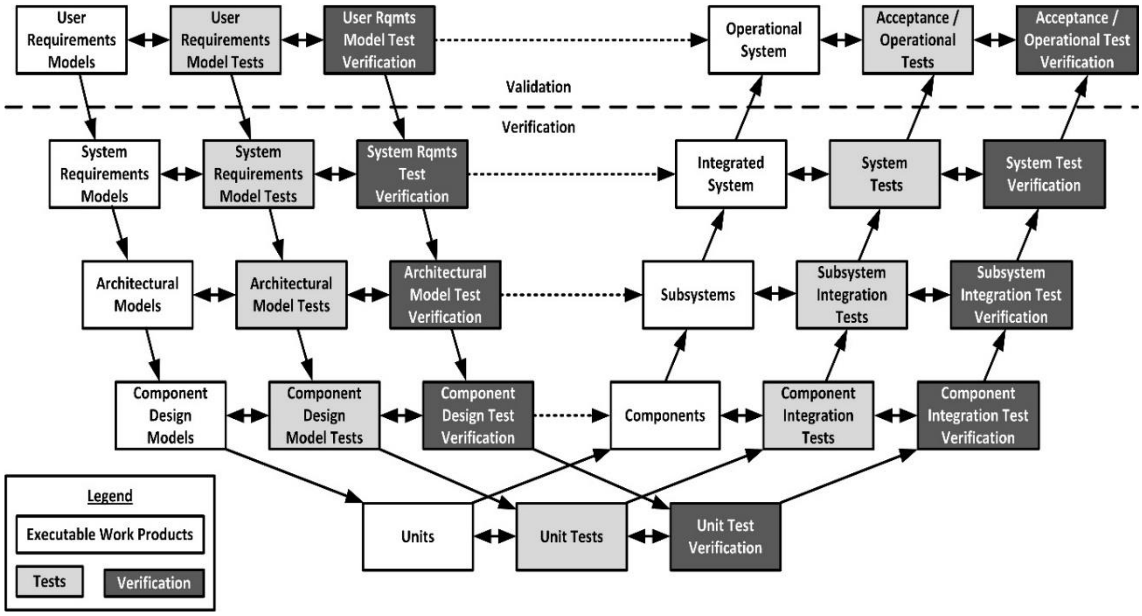

Figure 7. Triple V-model.

The final variant of the traditional V model, the triple V model shown in Figure 6, has three interwoven V models. The left V model shows the main products that must be tested. The middle V model shows the types of tests that are used to verify and validate these products. The right V model shows the verification of these testing products in the middle V. The triple V model uses the term verification rather than tests because the tests are most often verified by analysis, inspection, and review. The triple V is also good for very complex systems, so for that reason for example NASA could use the triple V-model when developing space products. Those systems have software and hardware modules that are integrated together.

2.8 Analysis and consideration of the methods

Choosing the concept can be done in several ways. One way is to use two step selection methodology, the first step concept screening and second step is concept scoring. In simple design decisions concept screening is often sufficient. Both of the selection methods include same steps:

1. Prepare the selection matrix
2. Rate the concepts
3. Rank the concepts
4. Combine and improve the concepts
5. Select one or more concepts
6. Reflect on the results and the process.

Concept screening is a method that is an evolution of Stuart Pughs method. The purpose of this method is to narrow the number of concepts and to improve the concepts. Stuart Pugh’s method is also known as decision-matrix method or Pugh concept selection method. [20]

Another method concept scoring is generally used when increased resolution will better differentiate among competing concepts. [19]

In this case the method for the analysis of a model is to create a product-driven development table using concept scoring. Concept screening is not necessary due the small amount of the analyzed models. There are several other ways to analyze different models, but this was found clear enough to be used in this thesis.

	V-model	Waterfall-model	Agile-model	interviewee 1	interviewee 2	interviewee 3	total score
Clarity	3	3	1				
>How easy it is to understand the model	3	3	2				
Phasing	2	3	1	2	2		4
>chronnological phasing	2	3	1				
>Worker load distribution	3	2	2				
User-friendly	3	3	3			2	2
Defining people’s responsibilities	3	2	3			2	2
Documenting the nonconformities	3	3	3		2	2	4
>corrective actions after the nonconformity	3	2	3				
>document management of nonconformities	3	3	3				
>documentation of the corrective actions after the nonconformity	3	2	3				
Flexibility	3	1	2	2			2
Scaling of the model	3	3	3	2	2		4

Table 1 Concept scoring table with criteria analyzed and weighted

The product-driven development chart was used over the customer driven because there already is a product that is used. It is just so abstract that it has no clear model in the background. If a customer-driven development chart would have been used the chart would be very much longer. Also, the customer-driven development may have aspects that are not easy to integrate in the shipbuilding process. The scale of the PDD chart is from 1 to 3 and it has weighted score and ranking. The specifications that were rated were thought so, that they take into count the systems that are already used in practice.

The criteria were developed by me, but they are results of four interviews. This means that the research method for criteria was an interview research. The questions used to gather criteria were:

1. What things are important for the verification system from users view of angle?
2. Should the verification system be integrated in the production system?
3. How the nonconformities should be taken into count?
4. Should the same system be used in both simple and complex assemblies?

After the table criteria were listed, the concept scoring was made. The weights were created also by interview research. Every interviewee had six points that they could use for different criteria. [25]

Only the three models were compared because they suit best for this kind of verification method. The chart has some specifications that are highly valuable if the model will be used in practice. After all the V-model was the best with these specifications, the

Waterfall model came in second and the Agile model was the least suitable with these specifications rated.

	V-model	Waterfall-model	Agile-model
Clarity	3	3	1
>How easy it is to understand the model	3	3	2
Phasing	8	12	4
>chronnological phasing	2	3	1
>Worker load distribution	3	2	2
User-friendly	6	6	6
Defining people's responsibilities	6	4	6
Documenting the nonconformities	12	12	12
>corrective actions after the nonconformity	3	2	3
>document management of nonconformities	3	3	3
>documentation of the corrective actions after the nonconformity	3	2	3
Flexibility	6	2	4
Scaling of the model	12	12	12
Total weighted scores	70	66	59
Rank	1	2	3

Table 2 Concept scoring table with weighted scores and ranks

3. EXPERIENCES FROM WORK PRACTICES

3.1 RCCL verification methods

RCCL had a newbuild in Meyer's shipyard in Turku Finland during the year 2018. I became acquainted with the RCCL's verification methods at the end of the shipbuilding process in November 2018. At the same time there was also an inspector from the classification society who was verifying that the IMO class rules were applied.

The RCCL inspector and the classification society inspector worked in close collaboration. The work assignor was the project leader from the shipyard and also on several occasions the suppliers, or the sub-contractors project leader was present.

The RCCL inspector was basically just inspecting and observing when the shipyard's personnel and the ship crew made tests. For example, we tested the seawater cooling system. First we walked through the main pipeline and made an overall view of the piping. The welding of the pipeline had been checked in the factory and the pipeline was under the pressure that it was designed for testing. The test pressure was registered in the documentation. After that, the ship crew ran each pump from the machine control room and we were down in the pump room with the pumps, checking that they worked correctly, made no vibrations or special noises and were numbered and identified in the correct way.

After that, the valve sensors were tested to verify that they were working properly. Again, the ship crew ran the valves from the machinery control room, and we observed the valves. The purpose was to verify that when the control room monitor shows that the valve is 100% or 50% open or closed, the valve actually is in the correct position. There was a flaw that when the control room showed it was 100% closed the actual valve was still a little bit open. This was written down in the verification document. Also, one verified thing was the numbering of the valves and that they matched the correct symbols in the machinery control room monitor. The work required a lot of investigation to find how the systems are designed to work. It came clear that for a smooth testing everything had to be checked through before going to the ship. If something was unclear, it was hard to find out any actual facts about the system on site.

3.2 The interview

I interviewed representatives of the Finnish navy purchasing organization known as the logistics institution. Finland has bought three bigger minesweeping ships a few years ago and two of the main project leaders were our interviewees. The last ship of the class was delivered in 2016. The two navy personnel who were our interviewees were responsible for the fulfillment of the customer's requirements by the shipyard. The other interview was answered by e-mail. Finland is now planning to buy four bigger corvettes so that the last ship could be in operative use by 2028. [10] Both men who answered in the interview have also a role in the newbuild. One complete interview is in the appendix A. The interviews aimed at understanding how Finland ensures that the naval ships they use are made according the rules and requirements set by the navy. Because Finland is a NATO partner country, many aspects of shipbuilding and ship repairing are tied to the NATO standards. According to the interview, the logistics institution follows these NATO standards for quality assurance. The standard that is mostly applied is AQAP 2110. It was clear that they did not follow any traditional development model, or at least they were not aware that they used any type of developing model. When asked about the V-model, one of the interviewees said that he basically does things according to the V-model but he did not know about the V-model.

3.3 Previous experience from Raikon Konepaja Oy

I have been working for Raikon Konepaja Oy for several years. Raikon Konepaja Oy is a family owned company and I am the general manager of the company. Raikon Konepaja has 14 workers. Raikon Konepaja Oy works in repairing and perpetuating service. It does not have any longer a product developed and sold, but it used to make dredges and pumps 40 years ago that were sold all over the world. The company has been in the same area in Rusko, Finland, since it was founded 1949. Raikon Konepaja Oy begun to work with navy in the 1986 when the last missile boat of Helsinki-class was taken to operative use. Raikon Konepaja had a significant know-how of the ship and its propulsion systems. The crew of Raikon Konepaja has been working since then with the navy, even though the Helsinki-class has already been sold to Croatia. One problem working with the navy is that nowadays Finnish navy has to make purchases through Millog Oy, which is a private company that is making profit from deals made with the Finnish navy. For Raikon Konepaja, shipbuilding and ship repairing is still a big part of the revenue. Raikon Konepaja Oy also has a solid know how about the earth moving machinery, and in our daily basis we fix parts of excavators, crushers, or trucks.

3.4 Previous experience from dockings

I have been responsible for several classification dockings for the navy ships during the years 2012-2016 and have gathered some experience about the methods used in the repair and inspection of ships already in use. Before being the person responsible of the dockings, I had been working in the dockings since 2008. After all, it is not that much different if a newbuild is being constructed or if there is a major docking where there are several work areas. In fact, docking can be more challenging because of the schedules being so tight and always something unexpected occurs that needs to be repaired also.

I was in the docking process from the very beginning when the quoted price of the docking was calculated. After that was the actual docking and I was responsible for the verification of the works and repairs done. My job mainly was to verify that the works were done as required and then I obtained the signature of the person responsible of the supplier company, the company I was working for, and then the signature of the person responsible from the customer. It was complicated to ensure that everything was made as the customer required and I had to keep in mind what was offered in the official quoted price, since the supplier cannot do work or repairs that are not paid. This work was very helpful to understand how things are done on the site.

3.5 Conclusions based on the experience

The previous experience from work practices has clearly shown that there are still issues in verification methods. Things are verified with too little information about the acceptance methods. This has led to accepting assemblies that are not ready or have serious issues that are found later, when the vessel is already in operation.

The verification methods are very closely related to the design and development process flow. This highlights that the verification and acceptance methods must be designed properly and not be neglected.

4. ANALYSIS OF THE DEVELOPED V-MODEL

The V-model is a way of thinking that can be also described as a model that could be integrated into a standard of project management or standard of quality management. It is clear that different development methods fit for different kinds of projects and organizations. After the background research, the V-model has been adapted to suit marine projects that are either newbuilds or ship dockings.

The V-model is highly suitable for marine projects because marine system projects are typically:

- New designs or new developments based in older similar products
- Included in many different business areas such as:
  - Theory and calculations of the system
  - The product installation
  - The software coding
  - Every product aims to bring money to the supplier so everything should be done efficiently
- Have a tight time schedule
- Including several workers in different areas and usually few project leaders

The V-model is especially suitable for shipyards, but the future of shipbuilding is going to the cheaper countries and cheaper shipyards. For that reason, also the shipowner organizations need to ensure that even if the manufacturing country is a low quality bulk factory country, the requirements are met. The shipowner should not rely completely on the system of the shipyard because the shipyard might not have the right know-how if it is a special system or a new kind of design. Also, as the shipowner receives the worst economical impact if something happens, it should be ensured that the product acquired is made according to standards and correctly tested.

It is much easier to fix and figure out the main causes at the shipyard than after the delivery when the ship is already in operational use. Furthermore, at the shipyard the responsible is the shipyard, not the owner of the ship because the ship has not been delivered yet.

5. EXAMPLE STUDY

5.1 Choice of the sample case

The V-model sample case was chosen so that as many as possible vessel types have one system like the sample, and the sample was supposed to have several different subassemblies. The sample was also chosen so that it is not too complex to be understandable in this thesis context. Machinery system was one option but it can be very complicated and too large as an example for a thesis. The sample case is used to clarify the V-model in the shipbuilding industry, especially in ship machineries.

The bilge water system is a system that every ship must have. From the smallest private use day cruisers that might have only a manual bilge pump, to the biggest container ships and cruise ships that have several huge dedicated pumps and pipelines across the ship, the bilge water system is ubiquitous. There are several rules about the bilge water system and how the system's subassemblies must work. IMO has rules about how it should work, and the purpose of the vessel has a great influence on the type of the bilge water system. For example, a navy ship must have a very strong and fast bilge water system and it also needs to have several spare systems in case of an emergency. Usually a bilge water system is at least duplicated or triplicated because of its nature. It is of course critical to be able to pump the excess water out from the ship in the daily use and especially in case of an emergency when the water pumping system might save the vessel or save minutes when the vessel is floating before it can no longer be rescued. Even though the size and capacity of a bilge water system is vessel-specific, the basics are the same. Water needs to be pumped out from the bilge at a certain flow rate. The V-model of the bilge water system is in the appendix B.

5.2 The bilge water system

First, the machinery box is in the V-model. The box or folder contains several files about different machinery systems, for example, from:

- The bilge water system
- The mooring system
- The engine room ventilation system
- The propulsion system
- The HVAC of the cabins

There are general design notes and requirements of the system. The IMO rules of the system requirements must be included in the listing as well. In the case of the bilge water system, there should be information about the required capacity of the system such as how much water needs to be pumped. These capacity requirements are based on IMO rules and in special purpose vessels there might be other laws and rules that need to be followed.

The second box has information of the subassemblies. This means that there are no general rules anymore, there are more specified rules about each subassembly and they need to be fulfilled. In the case of the bilge water system the subassemblies are:

- Pumps
- Pipelines
- Valves
- Tanks
- Penetrations

The testing of the subassembly is developed simultaneously as the subassembly itself is being designed and developed.

Then there is a list of the subassemblies' requirements and specifications. In the same document where the requirements are, the verification methods are also found. In this example, the capabilities of the pump and how these are measured are in the pump document.

The pump check document could include for example the next information:

- Pump tag
- Description of the pump
- Pump capacity
- Information of the pump's control board
- Pump tag in the software
- Maximum flowrate or pressure the pump could produce
- Limit switches functioning so that the pump won't run dry
- Date of check

Pipelines have documents about the routes and how to check welds of the pipeline. The pipeline checking document could include for example the next information:

- Test pressure
- Pipeline tags
- Description of the pipeline (what liquid and from where it is flowing)
- Verification about the weld inspection at the factory

- Other notifications if there is a route change or similar
- Date of check

Valves are listed and numbered, and their type must be decided and designed already at an early phase.

The valve checking document could include for example the next information:

- Valve tag or number
- Description of the valve
- Test unit (%, temperature, pressure, etc.)
- The valve tag in the software
- Are the valves in the correct position and do the manual emergency features work
- Date of check

Tanks are in this V-model and the tanks are also found in the more general list of all tanks on the ship. The general list of the tanks is something the ship needs to have in its onboard documents. In the system specified V-model, the tanks are checked only according to the system they are tied to.

The tank checking document could include for example the following information:

- Tank inspection date
- Verification that the welds of the tank have been checked in the factory or in a previous phase.
- Tank paint quality
- What paints are used, which is a major issue because different types of paints are used in different tanks

Penetrations are checked when the welding is done, so they need to be verified in previous phases, but there needs to be information that they have been verified.

When the components are verified, the system integration is tested. This means that the components need to work together correctly, and that the software works with the other ship user interfaces.

6. CONCLUSIONS

6.1 Background for these conclusions

Because this thesis has been made for a small consulting company in Turku, Finland, the results and conclusions are made keeping a few primary things in mind. First the project had a relatively narrow focus area. The focus was on the ship's mechanical systems such as propulsion, HVAC-systems, mooring systems, and so on. The company is involved in project management consulting, so the thesis was written with this in mind. This means that the concepts are abstract and the mentality is in the project management, not in the project itself. The approach is a standard-like approach; general guidelines are being kept in mind, not how to exactly make or perform certain parts of the project but instead what things every person of the project should have in mind when performing their own task.

The thesis includes first the backgrounds of the company and the research question. After that came the theoretical part which included theory of different models that can be used in the verification process. The researched models were the Agile model, the Waterfall model and the V-model. All these models can be used in software developing, but they are also usable in more traditional technologies. A search matrix was also used and some of the references are from the search matrix table. In the theory part is also a part about general process management to understand the aim of this thesis.

After the theoretical part comes the experience from work practice. I have experience from my previous work life. I was in the docking process from the very beginning when the quoted price of the docking was calculated. After that came the actual docking and I was responsible for the verification of the works and repairs done. Mainly I checked that the works were done as required and then I got the signature of the responsible person of the supplier company and then the signature of the responsible person of the customer. It was complicated to ensure that everything was made as the customer required, at the same time keeping in mind what was offered in the official quoted price so that the supplier do not need to do work or repairs that are not to be paid. This work was very helpful to understand how things are done on the site. After the dockings I decided to write my thesis about quality management systems for the same company I worked for so that I could get some experience of the system behind the work guidelines. This previous experience summed up to the idea and subject of this master's thesis.

During the beginning of this master's thesis I visited Meyer Turku shipyard where there was a newbuild for RCCL. There I became familiar with the RCCL verification methods with the help of one of the RCCL workers. At first, we agreed on what would be inspected and the schedule of the weeks' inspections. After that, the inspector gathered some information about the assemblies being tested and checked the test methods for each system. When the background research was done at the office, we headed to the ship and there was the project manager of the shipyard who had the authority to "sell" the assembly to the customer. Then we followed the procedure of the validation tests and after that the job was confirmed by both to the JIRA database. Seeing this method and how it works in real life gave me valuable experience about the verification process in a relatively big shipyard that makes the world's biggest cruise ships and with a customer that has several newbuilds in many countries at the same time.

Also, my visit to the Finnish navy purchasing organization known as the logistics institution was very helpful to understand how things are verified and how the process runs. I got to know about the previous newbuild that was completed in 2016 and about the ongoing project that is now in its design phase. I got more information about the process management and less details about the onsite work. All this theoretical and practical background while keeping in mind the companies' size leads to the conclusions of this master's thesis.

6.2 Why the V-model

The V-model Is a model or standard that is widely used around the world and is also used by NASA and the US military, so it has good references. The system was originally created for software engineers to understand how the process of creating a software goes and how to verify each part of the software. This can be applied in a construction that has many assemblies and subassemblies. It is also a method that suits well for products that are not made in serial production but instead can be one of a kind.

The V-model suits well for ship construction process from the customer's point of view. When the customer can use cheaper shipyards and because the customer can rely on its own verification methods and process management, the end product will result as designed and the price tag can be much lower due to the less process management done by the shipyard.

The V-model is easy to understand, and it has a timeline which is essential in a large-scale project. This means the flow of the process moves chronologically so it is easy for a person to realize when a certain part of the process must be completed so that the entire assembly goes smoothly. The V-model had the best points in the PDD comparison, and this is a research method that can be very reliable if the table is made correctly. This was a strong indicator that the V-model should be researched more and eventually be used as the result of this master's thesis.

The steps in the V-model may be something that people in the process management might already use, but without realizing that the methods they are using can be shown graphically. Graphical process flow helps to understand and people learn and remember best when they have something concrete to memorize.

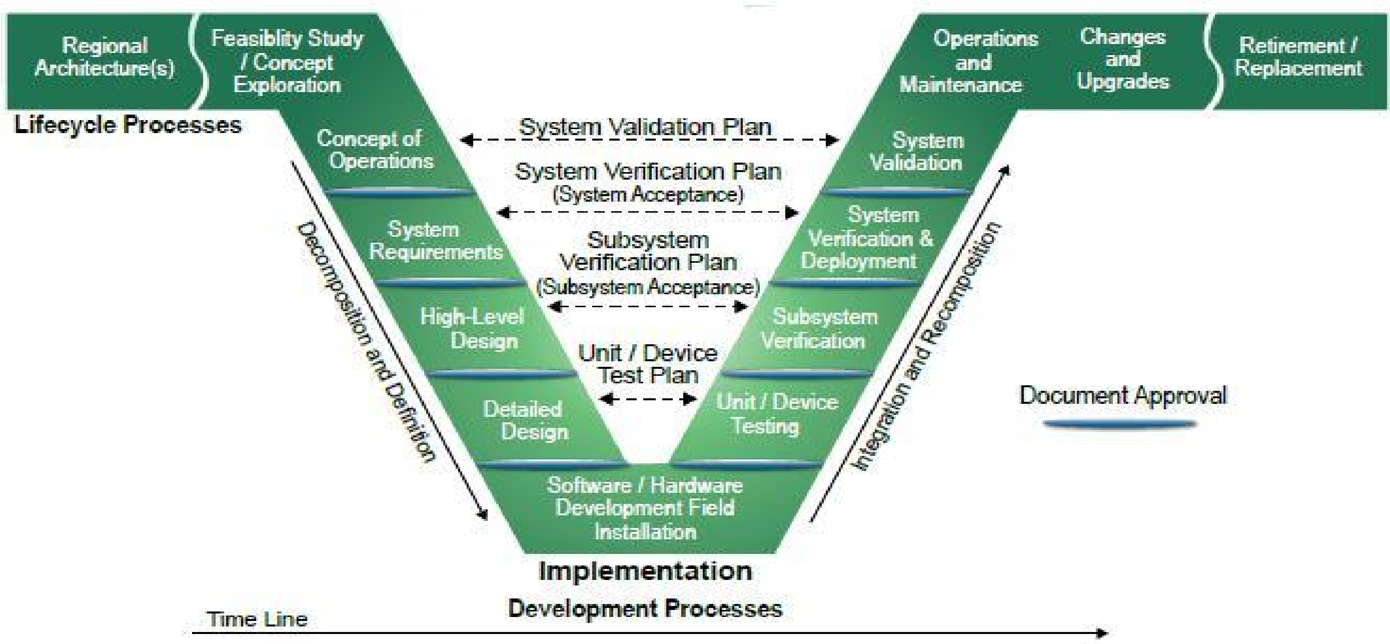

Figure 8. V-model [11]

6.3 Further research

In further researches, the V-model can be integrated with a schedule so that the verification dates are registered in the general process flow of the subassembly and in the entire assembly as well. This helps to understand when the subassemblies need to be factory tested and when they need to be installed in the ship and integrated with other systems of the ship. In the shipyards' process management, the timelines are critical because the schedule comes from the customer and the process must be adapted to their needs. If the timeline has been integrated to the verification dates, this could simplify the process management.

Further research could also look into how the V-model could be used in a shipyard. In Finland many shipyards use the Agile model that is converted to a ship designing spiral. This thesis considers the V-model from the customer's point of view.

In further researches, one area that should also be explored is how to integrate the V-model to an already existing database where the documents are stored and verified. I think that the level of detail is enough in the V-model, so that going into further detail in an assembly is not more efficient but just time consuming and can make a relatively simple assembly too complicated due the paperwork behind the assembling. There is a good way of thinking that should be used in all efficient shipyards. As it also fits the V-model since it all aims to a flowing process. That way of thinking is: *Everything that does not bring value for the customer is unnecessary.*

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APPENDIX A: INTERVIEW

Interview about acceptance methods

1. *What is the verification process of the ship's technical systems and is there a description of the process?*
    a. There is no actual process description. Every project is a new process and there is a ship technical institution that develops a process for the certain project. One previous class was made with a analysis requirement and the now under building class is made with technical requirement. The technical requirements are developed with the shipyard.
2. *What method is used for validating and accepting the ship technical systems? Is there for example a waterfall model or V-model used?*
    a. The validation methods for each step (FAT, HAT, SAT) are developed in co-operation with the system supplier. The shipyard does not have such a big role in the validation methods. There is no certain scheme of things used such as waterfall- or V-model. The different ship classes, such as support ships and destroyers have very different requirements.
3. *How are the verifications are phased? How are the design process and product development phrase taken into account*
    a. The product development is bought from a subcontractor. The design is accepted and at the same time the verification methods are accepted. The biggest responsibility in this office relating this area is to analyze if the testing methods are extensive enough. HAT is more wide ranging than SAT, but SAT has a big role in testing because it does not cost any more than HAT and for the navy sea operational ability is critical.
4. *What is the structure of validation methods?*
    a. There is no special structure. It relies on suppliers' documents and know-how of the purchaser. Usually the supplier wants to sell good

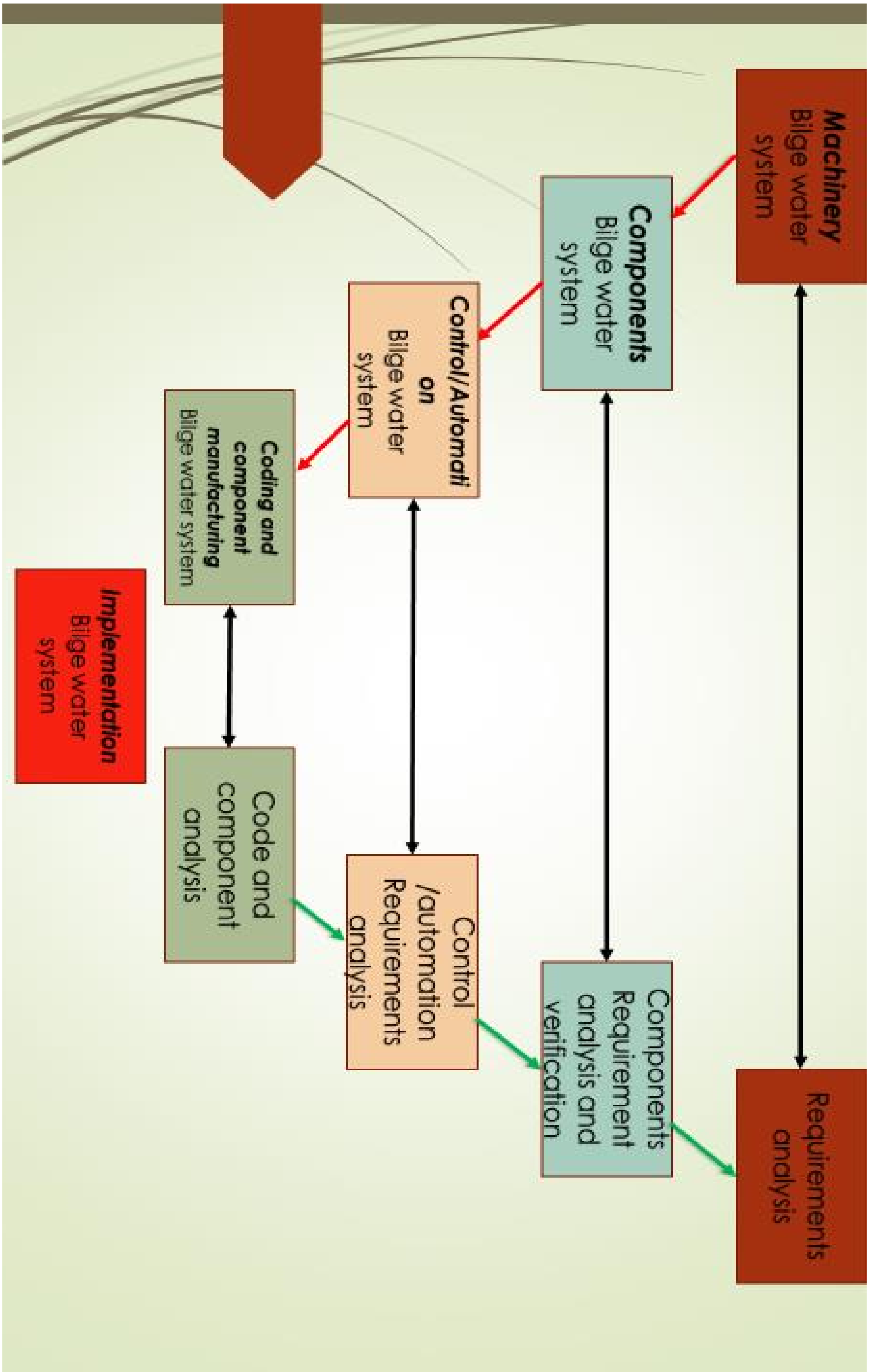
quality (and expensive) products and the shipyard wants to go the cheaper way.

5. *Is there a ship specified verification plan for ship technical systems? If yes, what kind of?*
    a. Yes there is a verification plan, it can also be part of the ship technical analysis. . It can also be system specified and produced in co-operation with the supplier and shipyard.
6. *How big are the verification totalities and in how small totalities can they be split? How does this refer to the workload of the inspectors?*
    a. The verification totalities are split in many very small pieces. For example in bilge water system the pipes are measured, all the valves are checked, pumps and motors are checked individually and so on.
7. *Is the verification system easy to use and/or logical?*
    a. It is an excel type chart or list that is filled. All the documents are found in either SAP or Krodonoc that are used as the document management system. The signature between supplier and purchaser is stored in SAP.
8. *How are the customers' requirements specified and how is the responsible person of customer organization defined?*
    a. There is one main negotiator who has the rights to make decisions on the design and development phase, he has few help hands also. The person is different in the construction phase but he knows the system.
9. *How the requirements are accepted?*
    a. The requirements are verified in the CAE system after a negotiation
10. *How are the requirements communicated to the shipyard?*
    a. In the negotiation is also the system supplier and personnel of the shipyard.
11. *How is the requirements' list being used?*
    a. Once a week there is a meeting with the supplier where the requirements are checked.
12. *How are the verifications scheduled?*

   a. The supplier gives a schedule where the verification phases are marked. Often the schedules change due to several reasons that cannot be affected.

13. *How are the verifications observed?*
    a. The schedule is all the time being watched. The project manager has a big role in keeping up with the verifications. There are daily meetings about the verifications of the day.
14. *How are the nonconformities listed? Are they acknowledged?*
    a. They are marked in the record and if it is not verified that it has been corrected it is shown in the system that has all the verification documents.
15. *What happens after the nonconformity has been registered?*
    a. First of all it is fixed as fast as possible if it can be done relatively easily. After it has been fixed, the system is tested. If the nonconformity cannot be acknowledged it can become a problem for the schedule of the project.
16. *Is there a person responsible so that the nonconformity does not happen again?*
    a. The systems project leader is responsible, he/she is the one who contacts the system supplier if needed.
17. *Are there any proficiency requirements for the inspectors?*
    a. There are general educational requirements and overall experience from work of the same category. The sectors are defined by experience, such as hull construction, technical systems, navigation systems etc.
18. *What is the importance of GQAR during the shipbuilding process?*
    a. It gives some general guides and guidelines. It specifies the schedule and what is made in each process. It is very useful when used correctly. It also provides some guidelines as to how the communication and documents should take place between the customer and shipyard.

APPENDIX B: V-MODEL



(Machinery) Bilge water system

- Mooring systems
- HVAC system
- Propulsion system
- Lightning system
- Fuel system
- Ballast systems
- Bilge water system
- Etc.

Requirements analysis

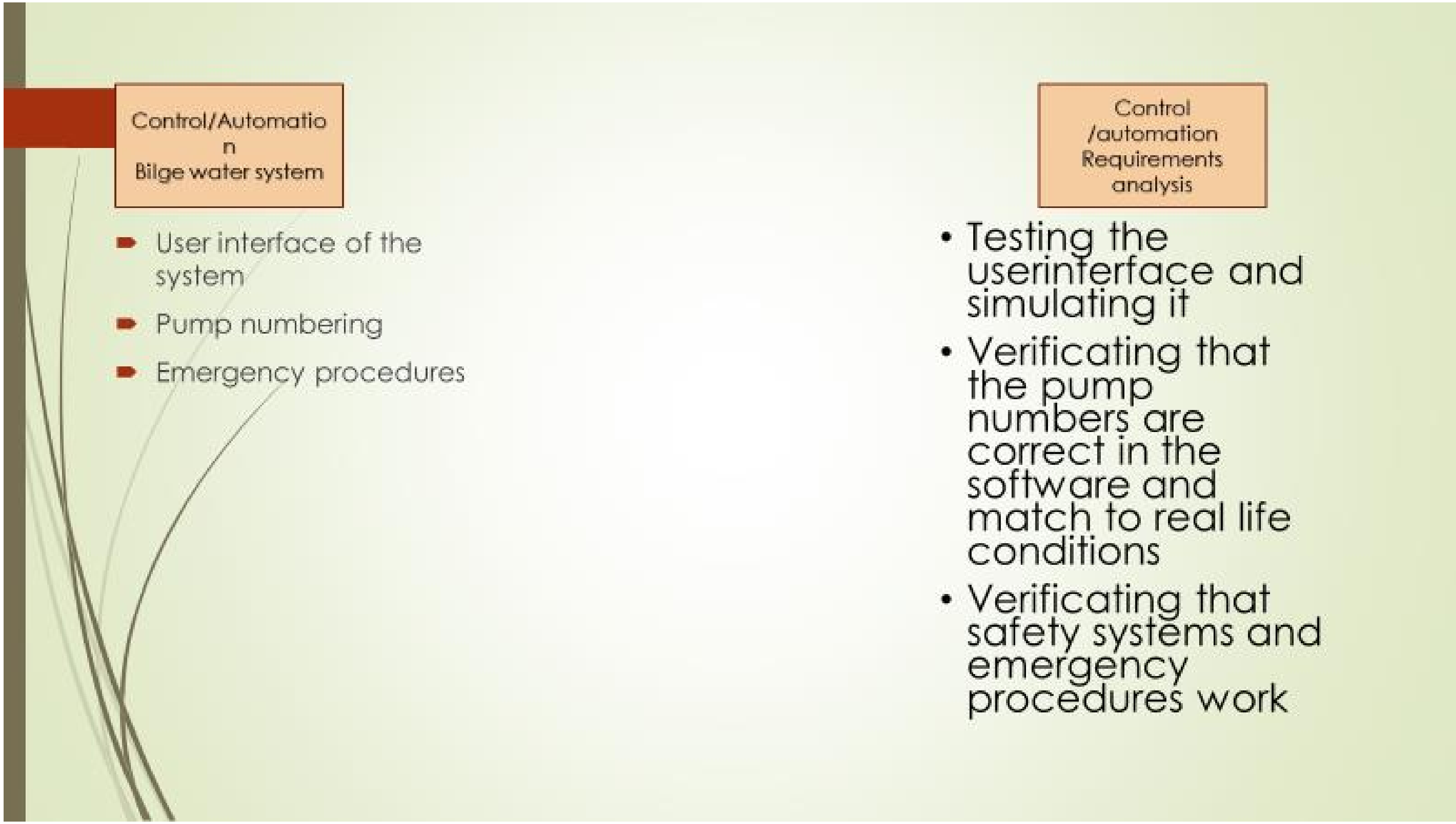
- General requirements of the bilge water system
- IMO rules have a big influence on the verification requirements of this level
- The verification requirements of the system are listed in generous matter and if the ship owner wishes to use a specific manufacturer it should be listed in this part
- How the components and software are integrated together and how this is verificated

Components Bilge water system

- Pipelines
  - Material
  - Routes
- Valves
  - Valve types
  - Valve locations
- Penetration
  - Insulation
- Pumps
  - Electric motors
  - Capacity
- Tanks

Components Requirement analysis

- Verification of integration between components and testing methods
- Pipelines
  - Materials that are used must be deisgned so that it does not cause corrosion problems and verification of this
  - Routes are designed so that they are easy to install and can be repaired
  - Dimensions are calculated so that the IMO requirements of the flowrate are fulfilled
- Valves
  - Valve types need to be specified
  - Valve locations need to be designed so that they can be repaired
- Penetration
  - Insulation
  - Rules about water tight lead-ins. Fulfilling the rules must be verified
- Pumps
  - Electric motors
  - How high the pump can pump water


Control/Automatio
n
Bilge water system
User interface of the system
Pump numbering
Emergency procedures
Control
/automation
Requirements
analysis
Testing the userinterface and simulating it
Verificating that the pump numbers are correct in the software and match to real life conditions
Verificating that safety systems and emergency procedures work

Coding and component manufacturing
Bilge water system

- Components that have smaller components such as the elctric motor
- Coding is part of the user interface
- Valves have smaller components that have major influence on the ability of the valve

Code and component analysis

- Electric motor has several smaller components that are critical for a good quality product. The verification of the motor needs to be done in the factory(FAT).
- Software coders already use V-model to verifythe code and portions of the code
- Valves are machined so the machined parts need to be measured correctly and the meaning values need to be clear already in the design.